Occurrence of *Cryptosporidium* in Japan and counter-measures in wastewater treatment plants

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Abstract The outbreak of cryptosporidiosis in Ogose in 1996 forced the wastewater treatment authorities to rethink the level of contamination by *Cryptosporidium* of wastewater and waters in the watersheds and counter-measures in wastewater treatment plants. A survey of *Cryptosporidium* concentrations in wastewater and treated wastewater conducted nationwide showed relatively low levels. Also, evaluation of wastewater treatment showed a 2 log oocyst removal with an activated sludge process and an additional 1 log removal with coagulant dosing.

Keywords *Cryptosporidium*; wastewater; treated wastewater; river water; wastewater treatment; activated sludge process; removal method

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Introduction

Japan experienced an outbreak of cryptosporidiosis in 1996 in the town of Ogose in the Saitama Prefecture, in which about 9,000 people were infected. The direct cause of the outbreak was that *Cryptosporidium* oocysts in source water were not removed completely by water treatment processes and the contaminated water was distributed through the tapwater system. However, the location of small wastewater treatment plants upstream of the water source were said to have enlarged the outbreak. The cycle of water from wastewater to drinking water through a river system was formed which led to the multiplication of *Cryptosporidium* in the cycle. As wastewater treatment was involved in the Ogose case, the *Cryptosporidium* concentrations in wastewater and treated wastewater were surveyed at plants where treated wastewater is reused for recreation impoundment and other purposes. In addition, levels of *Cryptosporidium* in major rivers of the Kanto area were also investigated. Experiments were carried out to investigate countermeasures to take against *Cryptosporidium* in wastewater treatment plants in order to reduce the concentration of oocysts in the treated wastewater.

Japanese status of Cryptosporidium concentration in water

Wastewater and reclaimed wastewater

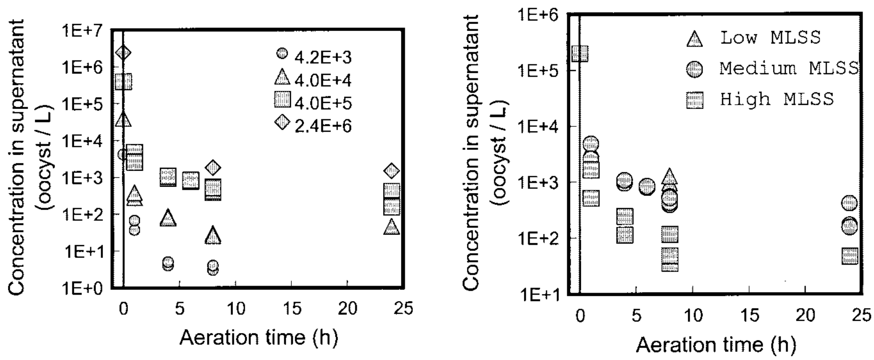
A survey was conducted in 1996 by the Public Works Research Institute (PWRI) to establish the levels of *Cryptosporidium* oocysts in wastewater across Japan. The survey focused on treatment plants that reused reclaimed wastewater for recreational impoundment. Samples of raw wastewater and reclaimed wastewater were collected from 67 wastewater treatment plants most of which were equipped with sand filters in addition to biological treatment for the purpose of reuse. The sample volume was basically 200 mL for raw wastewater and 20 L for reclaimed wastewater with indirect fluorescent antibody testing being used to detect oocysts. Results of the survey are summarised in Table 1. Both the positive ratio and detected concentrations were low compared with those reported in other countries; accordingly, the level of infection among people in Japan was thought to be low.

Table 1 Occurrence of *Cryptosporidium* in wastewater and reclaimed wastewater

Wastewater	Positive ratio	Range oocysts/L	Average recovery	Detection limit/L
Raw	7/73 (10%)	8 – 50	14%	3 – 33
Reclaimed	9/74 (12%)	0.05 – 1.6	46%	0.04 – 0.5

Table 2 Occurrence of *Cryptosporidium* in river water in the Kanto area

Rivers	Positive ratio	Range oocysts/L	Average recovery
Tone, Edo and Tama	3/48 (6%)	0.06 – 0.1	–
Ara	3/20 (15%)	0.05 – 0.06	22%
Oppe	1/20 (5%)	3.2	44%



Different number of added oocyst (MLSS:1,730 – 2,290mg/L)

Varied activated sludge concentration (Oocysts c4x10^5 (1/L)

Figure 1 Relationship between aeration time and oocyst concentration in supernatant

River water

Water samples were taken and measured periodically in major rivers in the Kanto area which are important water sources for Tokyo and surrounding cities. A survey was conducted in fiscal years 1996 and 1997. A high concentration of oocysts was detected in the Oppe River which runs through Ogose during the outbreak (Table 2) and the positive ratio was rather high for the Ara River which has Ogose in its watershed. However, in other rivers both the positive ratio and concentration were low.

Removal of oocysts in wastewater treatment plant

From the viewpoint of risk reduction, wastewater treatment plants must be prepared for an outbreak as a high concentration of oocysts flows into the plants during an outbreak resulting in increased levels in the treated wastewater. Oocyst removal efficiency of an activated sludge process was evaluated for wide range of inflow concentrations followed by investigation of a coagulant dosing method for improvement of oocyst removal.

Methods – the activated sludge of a municipal wastewater treatment plant was diluted and put into several vessels of 5 L with inactivated oocysts (4.2×10^3–2.4×10^6 oocyst/L). After being aerated (<25 h) the activated sludge was allowed to settle for 2 h and the supernatant recovered. The MLSS concentration varied from low (810–1,220 mg/L), medium (1,720–2,290 mg/L) to high (3,680–4,240 mg/L). Throughout the experiment, recovery of oocysts was 57.6% on average.

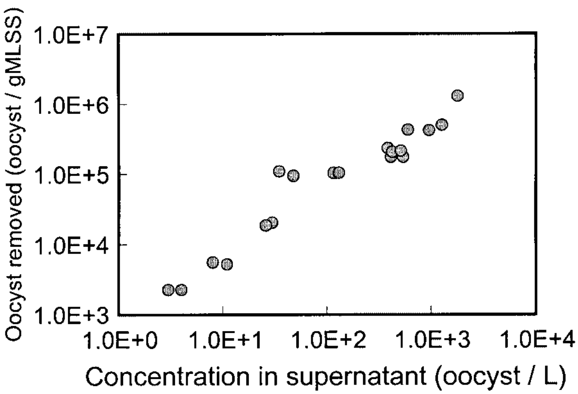


Figure 2 Relationship between oocyst concentration in supernatant and number of oocysts removed by activated sludge

Table 3 Calculated oocyst concentration in effluent and oocyst removal ratio

Oocysts/L		
Influent	**Effluent**	**% removal**
10	0.074	99.3
1,000	12	98.8
100,000	2,000	98.0

Results – the relationship between aeration time and oocyst concentration in the supernatant is shown in Figure 1 with different numbers of added oocysts and with varied activated sludge concentration. Oocyst concentration showed a rapid decrease within 1 h of aeration then a relatively slow decrease up to 8 h with a stable concentration after this time. The number of added oocysts and the activated sludge concentration had the effect of increasing the former and decreasing the latter in the oocyst concentration in the supernatant.

The oocyst removal capacity of the activated sludge was evaluated using the data of 8 h aeration. Figure 2 shows the relationship between oocyst concentration in the supernatant and number of oocysts removed by 1 g activated sludge. These two parameters showed correlation and the relation is expressed in Eq. 1:

$$R = 1039C^{0.90} \qquad (1)$$

where R = number of oocysts removed by 1g of activated sludge (oocyst/g MLSS) and C = oocyst concentration in the supernatant (oocyst/L).

In a municipal wastewater treatment plant, a large amount of oocysts may inflow continuously during an outbreak; therefore, the removal capacity of activated sludge would be decreased because the returned activated sludge may no longer have a removal capacity. The removal capacity under steady inflow of oocysts was calculated assuming the following: (1) plug flow in the aeration tank, (2) HRT of 8 h, (3) return activated sludge ratio $\ll 1$, (4) conversion ratio of 0.5 g MLSS/g S-BOD, 1.0g MLSS/g SS, (5) Endogenous respiration was ignored and (6) influent concentration of 80 mg S-BOD/L, 60 mg SS/L. From these assumptions, production of activated sludge (ΔX) which had an oocyst removal capacity was calculated as follows (Eq. 2):

$$\Delta X = 80\,[\text{mg S-BOD/L}] \times 0.5\,[\text{g MLSS/gS-BOD}] + 60\,[\text{mg SS/L}] \times 1.0\,[\text{g MLSS/gSS}]$$
$$= 0.1\,[\text{g MLSS/l}] \qquad (2)$$

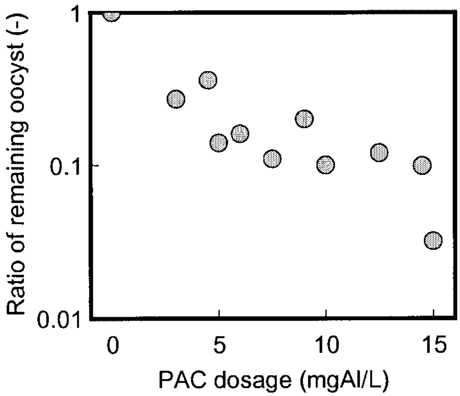


Figure 3 Effect of PAC dosage on oocyst removal

where ΔX is the produced activated sludge by treating 1 L of influent [g MLSS/L]. The mass balance of oocysts is expressed in Eq. 3.

$$Cin = C + R \cdot \Delta X \quad (3)$$

Solving Eqs. 1 and 3 simultaneously, the effluent oocyst concentration (C) against influent oocyst concentration (Cin) can be obtained as in Table 3.

To improve oocyst removal efficiency of an activated sludge process, poly-aluminium chloride (PAC) was dosed into activated sludge 1 h before the end of an 8 h aeration and oocyst concentration in the supernatant measured (Figure 3). As dosed PAC increased, the oocyst concentration in the supernatant decreased. An additional 90% removal could be expected if PAC was dosed >10mgAl/L.

From the experiment, oocyst removal efficiency was expected to be 2 log with an activated sludge process and an additional 1 log with coagulant addition, totalling 3 log at best. However, this level of removal may not be enough; if an outbreak is large, dilution of treated wastewater in rivers is small and the probability of human contact downstream is high. Thus, additional removal methods need to be investigated e.g. coagulation/sedimentation of raw wastewater, improvement of sand filtration and application of flotation.

Conclusions

A nationwide survey of the presence of *Cryptosporidium* in wastewaters, treated wastewaters and river waters in Japan revealed relatively low contamination at this time. Oocyst removal by activated sludge process was 2 log with biological treatment and an additional 1 log removal was achieved when coagulant dosing was also used.